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HOLOGRAPHIC DETERMINATION OF THE DROPLET SIZE DISTRIBUTION OF A SIMULATED DEFOLIANT SPRAY IN A 400-KNOT AIRSTREAM

ARO, INC.

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Holographic Determination of the Droplet Size Distribution of a Simulated Defoliant Spray in a 400-Knot Airstream

D. L. Davidson

FOREWORD

This report presents the results of a test to determine the feasibility of determining the droplet size distribution of a simulated defoliant spray in a high-velocity airstream using holography techniques. The work was performed by ARO, Inc., the contract operator of the Arnold Engineering Development Center (AEDC), Arnold Air Force Station, Tennessee, under Contract F40600-71-C-0002 with the Air Force Armament Laboratory, Eglin Air Force Base, Florida. The Project Monitor for the Armament Laboratory was Captain Rolf Richter (ADLMA). Testing was conducted during the period 27 January - 12 February 1970 in the Propulsion Development Test Cell (J-2) of the Engine Test Facility (ETF) at the Arnold Engineering Development Center.

The author wishes to acknowledge the efforts of Dr. Jim Trollinger and Mike Farmer of the Technical Staff of the Office of the Managing Director, ARO, Inc., for the development of the laser holograph used for this test and for their technical assistance in evaluating the holographic data obtained.

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This technical report has been reviewed and is approved.

John E. Hicks

JOHN E. HICKS, Colonel, USAF
Chief, Non-Explosive Munitions Division

ABSTRACT

The feasibility of determining the droplet size distribution of a simulated defoliant spray in a high-velocity airstream using in-line holographic photography was successfully demonstrated. Holographic droplet size data were obtained in the 400-knot airstream contained within a 37-inch-diameter duct at spray flow rates from 3 to 117 gpm and spray injection pressures from 16 to 64 psig. Average diameter of the spray droplets was approximately 21 microns. Droplet size distribution did not vary significantly with either spray flow rate or injection pressure. The holographic measurement system exhibited an apparent diametric resolution limit of approximately 10 microns. Operational reliability of the holograph was satisfactory.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (CONCLUDED)

LIST OF ABBREVIATIONS AND SYMBOLS

g	Dimensional constant, 32.17 lbm ft/lbf sec^2
M	Mach number
n	Number of measured spray droplets
p	Pressure, psia or psig
R	Gas constant for air, 53.34 lbf ft/lbm °R
T	Temperature, °R, unless otherwise noted
u	True airstream velocity, knots
$\dot{w}$	Mass flow rate, lbm/sec
x	Diameter of spray droplet, microns
$\bar{x}$	Average diameter of spray droplets, microns
$\bar{x}_m$	Average mass-weighted diameter of spray droplets, microns
γ	Ratio of specific heats for air, 1.400
ψ	Relative frequency of occurrence
i	Holograph airfoil
j	Spray fluid
k	Supply tank
ℓ	Nozzle supply line
r	Instrumentation rake
s	Static
t	Total

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SECTION I
INTRODUCTION

The design of aircraft spray nozzles for high-speed defoliant spraying is critical because the nozzles must create droplets that will be both large enough to overcome updraft and crosswind scattering and small enough to ensure even, efficient ground dispersion of the defoliant. Optimization of the spray nozzle design relies on an adequate knowledge of the relationships of nozzle flow rate, nozzle geometry, nozzle injection pressure, aircraft velocity, and other variables to spray droplet size distribution. However, these relationships are not well defined for airspeeds greater than 140 knots, and no proved technique of measuring droplet size in free fall exists. Recent developments (Ref. 1) in holography indicate that in-line holographic photography can provide a suitable measurement technique.

A test to demonstrate the feasibility of determining the droplet size distribution of a simulated defoliant spray in a high-velocity airstream using holography techniques was conducted in Propulsion Development Test Cell (J-2) of the Engine Test Facility between January 27 and February 12, 1970. Spray flow rate and injection pressure were varied during the test to demonstrate the ability to detect spray nozzle parametric relationships.

SECTION II
APPARATUS

2.1 TEST EQUIPMENT

Testing was accomplished by spraying a simulated defoliant from a single spray nozzle into the high-velocity flow contained within a 37-in.-diam duct. Spray droplet size distribution data were obtained in the duct downstream of the spray nozzle using a laser holograph.

2.1.1 Spray Test Section

The spray test section consisted of five sections of 37-in.-diam ducting (Fig. 1). An inlet bellmouth was attached to a 10-ft-long section of ducting that contained an inlet pressure and temperature rake together with the spray nozzle and associated fluid plumbing. The spray section was attached to a 23-ft-long extension duct and a 1.5-ft-long holographic instrumentation section. The axis of the holograph was 30 ft from the spray nozzle. A 4-ft-long thermal expansion duct section was attached to the downstream end of the instrumentation section to allow for expansion of the assembled duct sections (see Section 2.2).

2.1.2 Holograph

The holograph (Figs. 2 through 4) used for the test consists of a pulsed laser for illumination, two optical tubes for protecting the laser beam when not in the droplet field, a camera for recording the Fraunhoffer diffraction patterns resulting from passage of the laser beam through the droplet field, a lens for allowing the camera to be mounted outside the test section, and a low power continuous wave (cw) laser with associated equipment for aligning the holograph. The illumination laser (Fig. 4) was a 10-megawatt Q-switched ruby rod type which, in combination with a lens system, produced a 2-in.-diam coherent, monochromatic, collimated light beam of 6943 angstroms wavelength. An optical laser pulse monitor was used to ensure that the laser did not produce multiple pulses. The laser beam, when properly aligned, passed through the first optical tube which contained a 1-in.-diam optical stop, through 3.5 in. of the high-velocity spray droplet field in the center of the test section duct, and into the second optical tube. The 1-in.-diam beam was then focused by a 10-in. focal length, F5 lens onto the image plane of the camera located outside the duct. The 3.1-in.-diam (ID) optical tubes were supported inside the test section ducting by

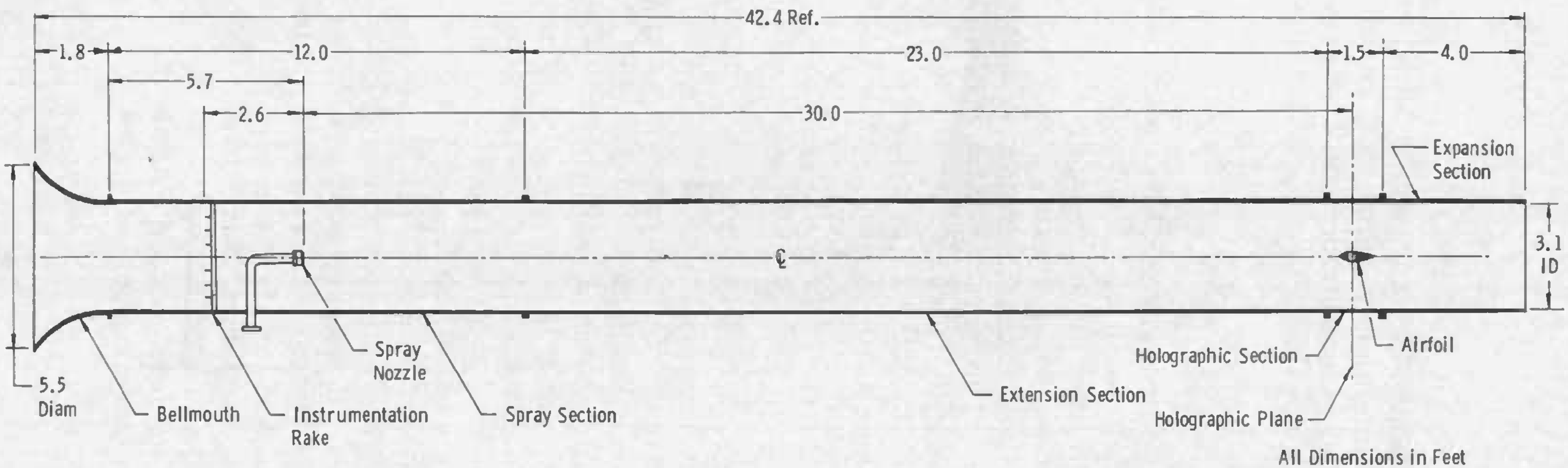

Figure 1. Test Section

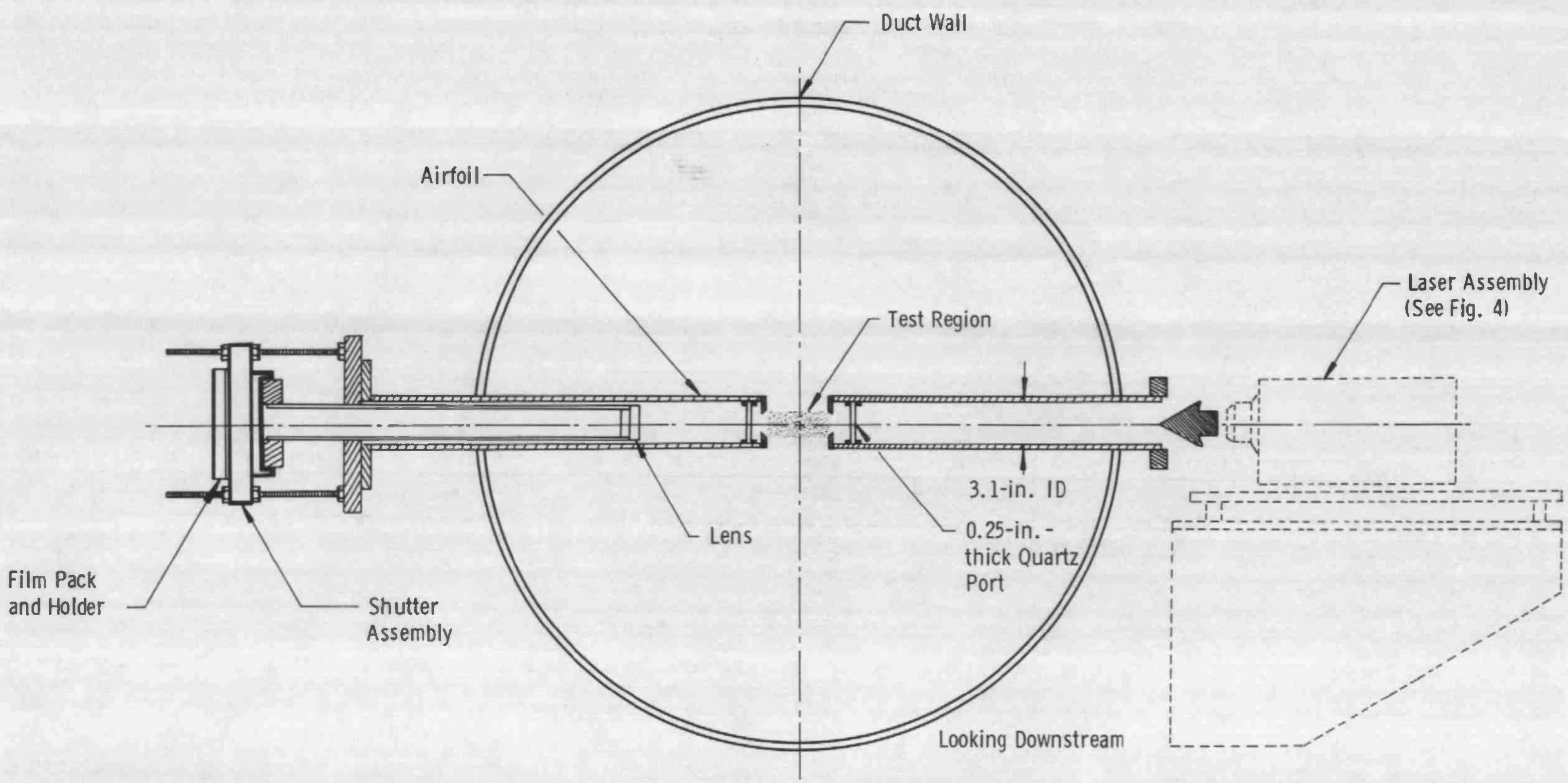

Figure 2. Schematic of Holograph

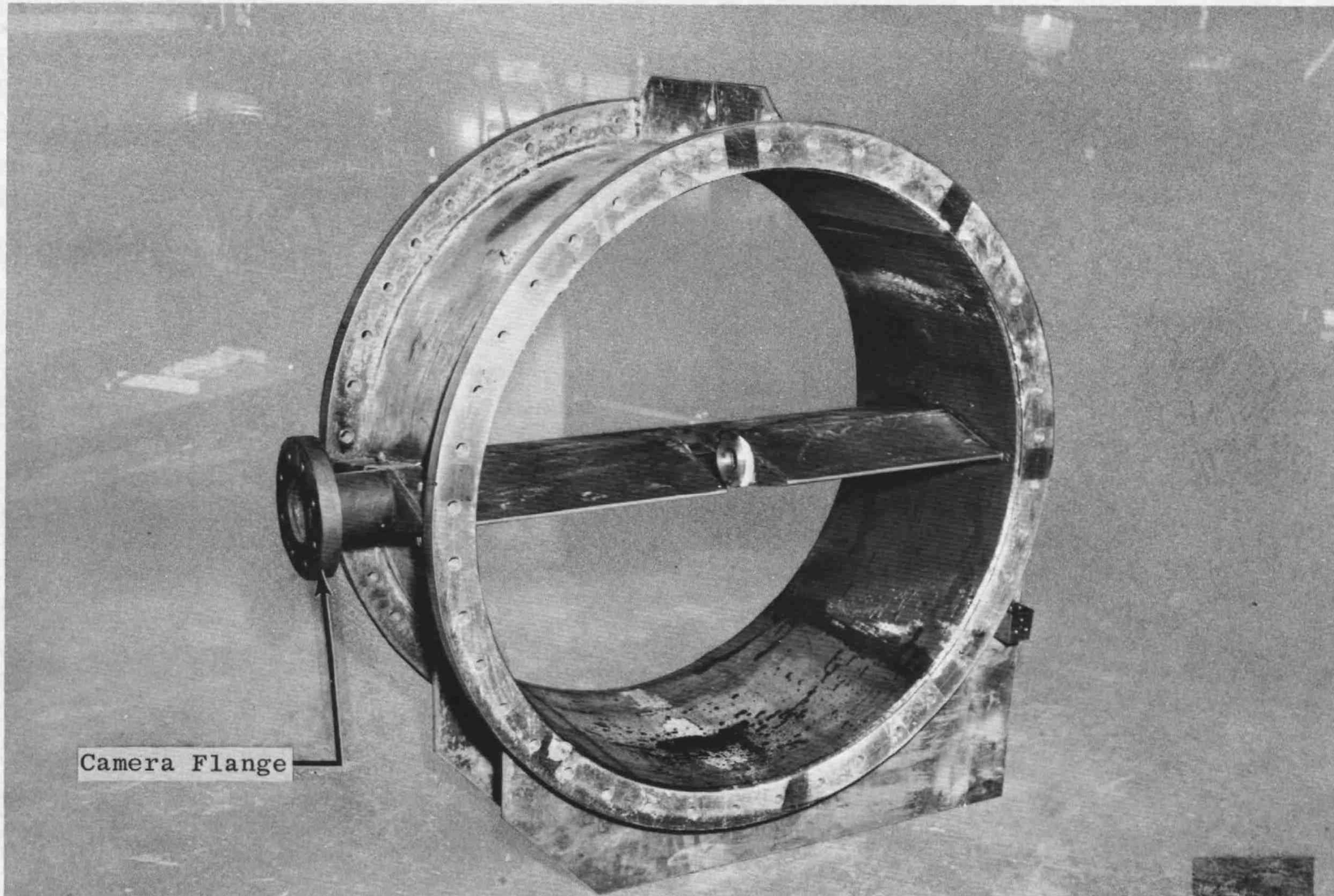

Figure 3. Holograph Duct Section

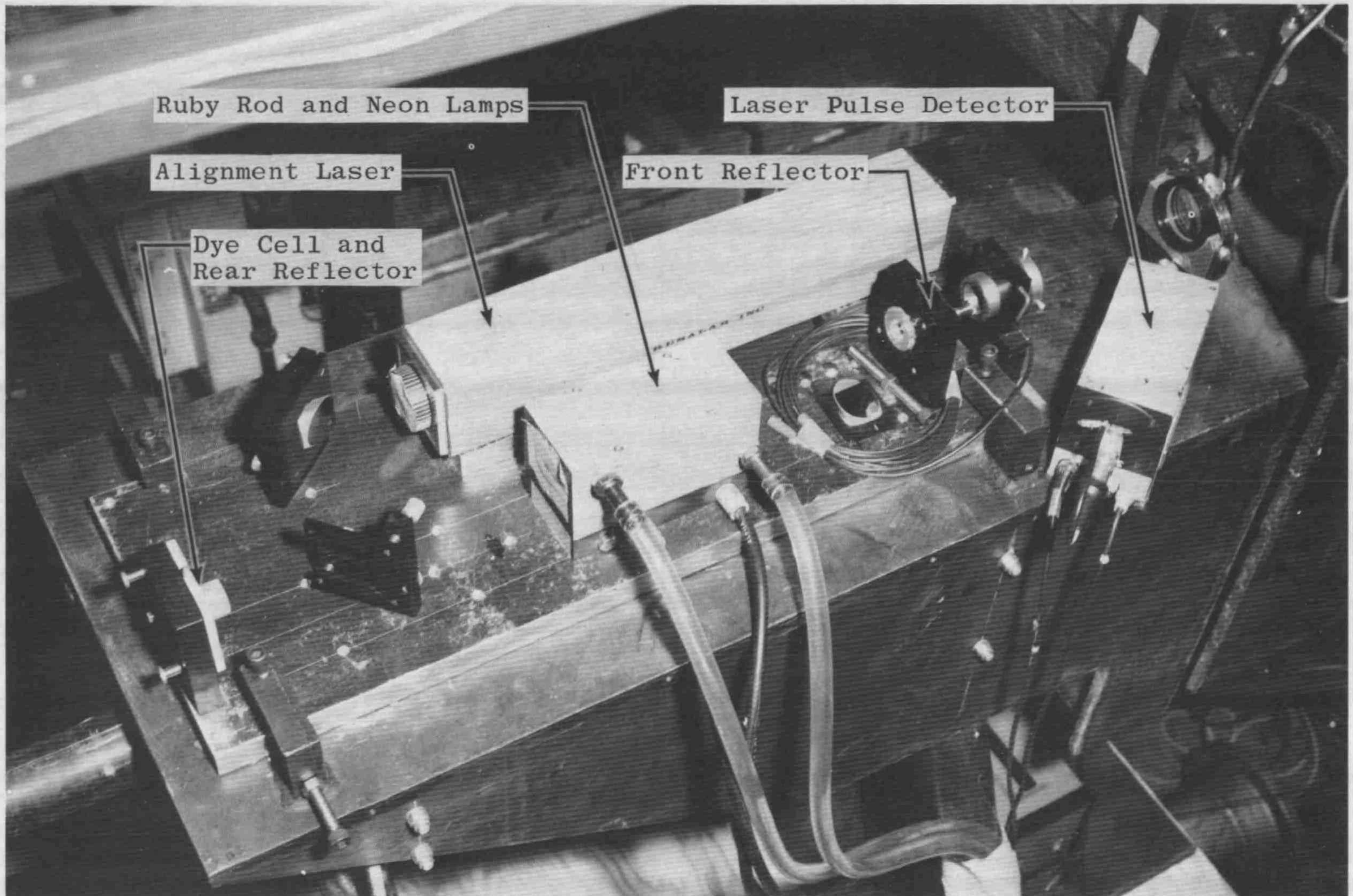

Figure 4. Holograph Laser Assembly

an airfoil (Fig. 5) and were capped inside the test section duct by 0.25-in.-thick quartz ports. The ports (Fig. 2) were purged externally with heated gaseous nitrogen to prevent spray fluid from impinging on the ports and spuriously scattering the laser light beam before or after it passed through the 3.5-in.-long by 1-in.-diam test volume of the spray droplet field. A 150-micron wire was cemented to the camera-side optical port to allow physical determination of the holograph optical magnification. A manually operated shutter fitted with a standard film holder formed the holograph camera (Fig. 6). Agfa-Gevaert 10E75AH film plates were used for photographic recording of the holographic droplet field images.

2.1.3 Spray Fluid

The spray fluid used during the test was a mixture (Table I) of water, glycerin, and sodium thiosulfate that duplicated the density, viscosity, and surface tension (Table II) of the military defoliant Blue. Methylene blue was added to provide coloration of the mixture. Laboratory analyses indicated close agreement between the corresponding physical properties of the simulant and defoliant Blue (see Section 4.2).

TABLE I. SPRAY FLUID CONSTITUENTS[1] (PERCENT BY WEIGHT)

Water	30.0
Glycerin	29.0
Sodium Thiosulfate	41.0
Methylene Blue	0.005
Igepal® CO-630 (surfactant)	0.005

TABLE II. PHYSICAL PROPERTIES OF AGENT BLUE[1]

Density	1.335 g/cm^3 at 75°F
Viscosity	8.8 centistokes at 77°F
Surface Tension	35 dynes/cm at 77°F

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[1] C. H. Glover, Quantitative Assessment, Vitro Services Division, Eglin, AFB, Florida, in response to ADTVE Letter 78-67.

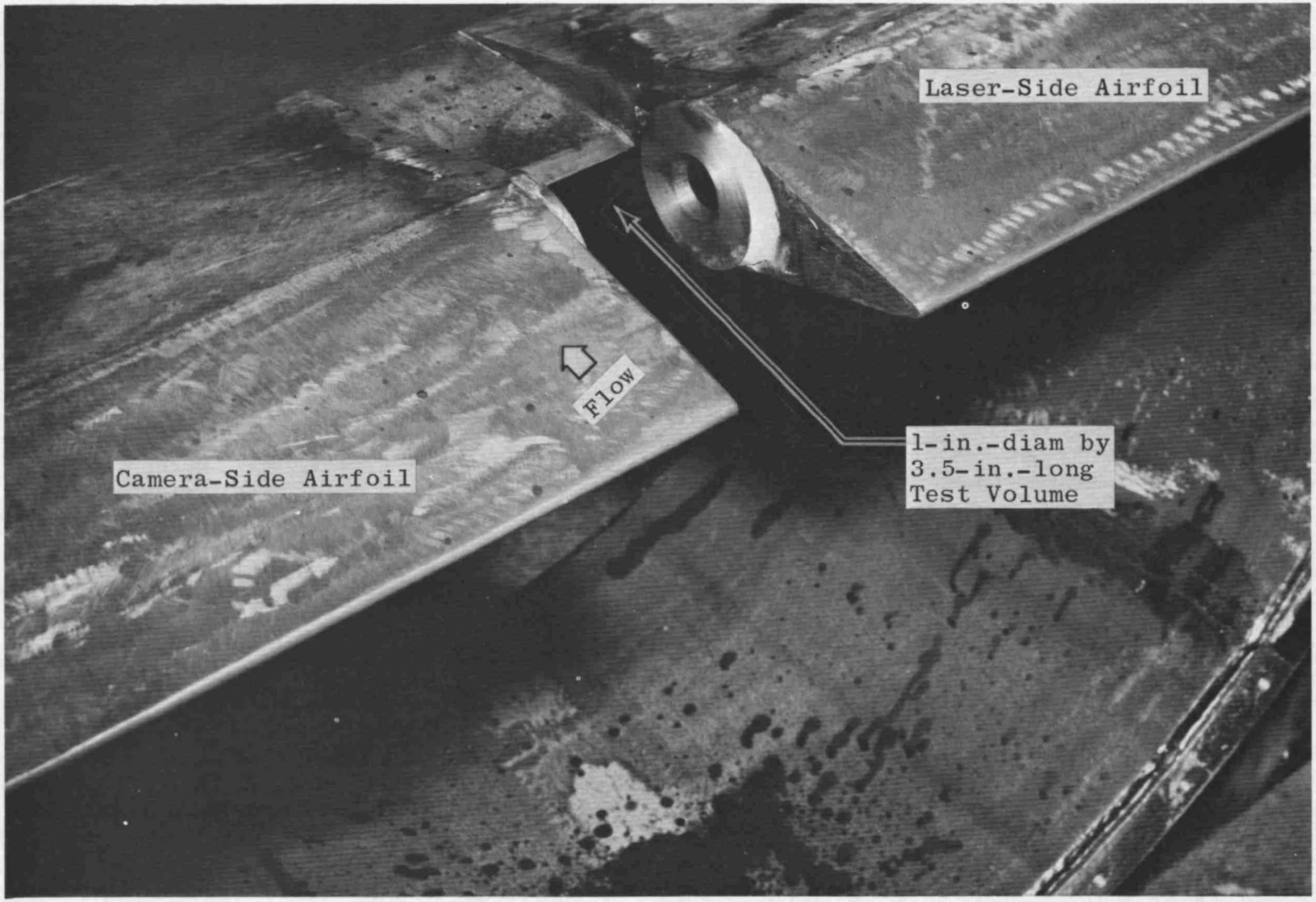


Figure 5. Holograph Airfoil and Test Volume

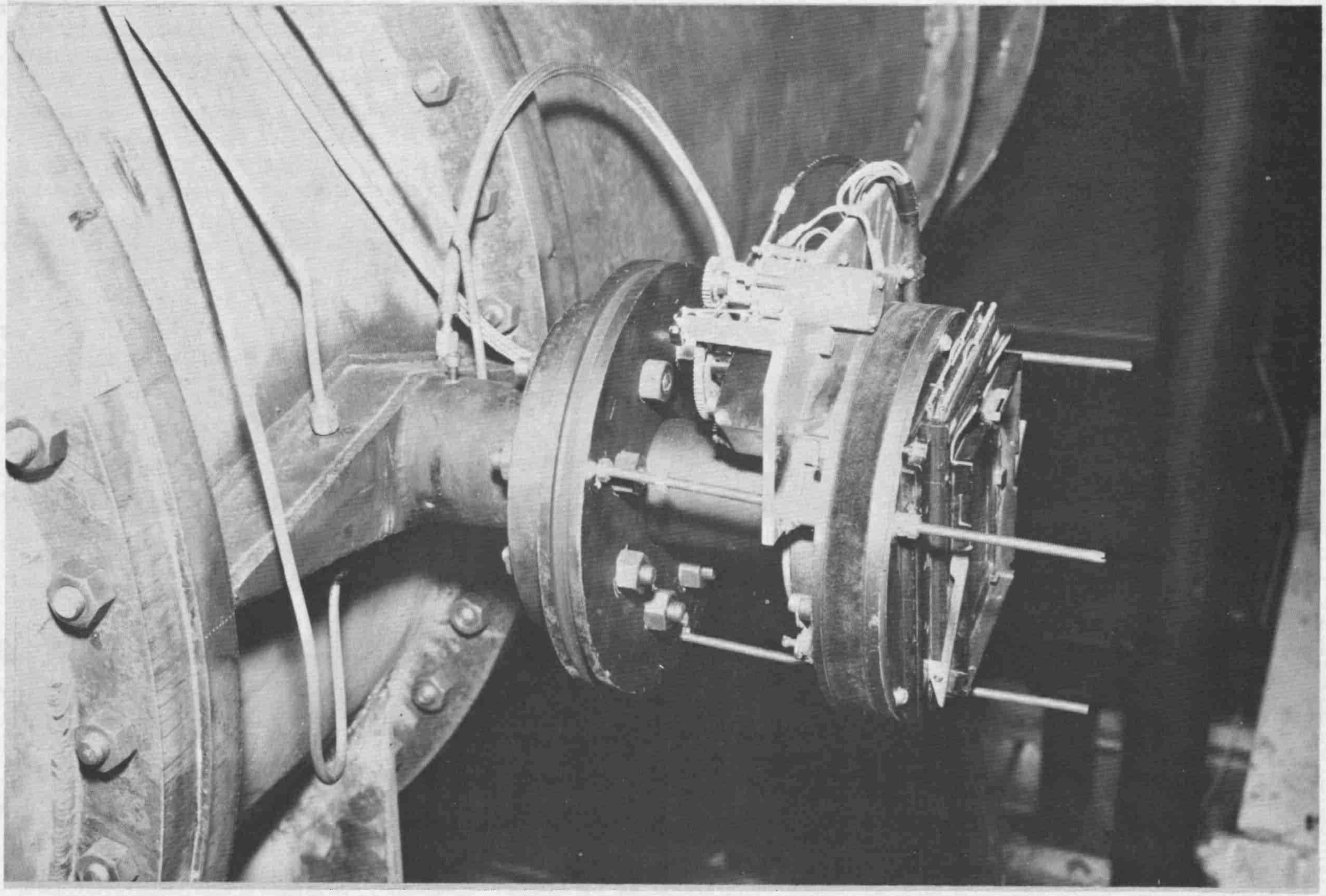


Figure 6. Holograph Camera

2.1.4 Fluid Supply System

The simulated defoliant was supplied from a 150-gal supply tank to the spray nozzle by a fluid supply system (Fig. 7). The gaseous nitrogen pressurized tank fed fluid to three 1-in. control valves through a 2-in. supply line. These valves were used both for stopping and starting the fluid flow and for selection of properly sized flow rate sensors. The outlets of these valves were manifolded into a single 2-in. supply line which supplied the simulated defoliant through the wall of the test section duct to the spray nozzle.

2.1.5 Spray Nozzle

The spray nozzle (Fig. 8) used for the test was fabricated of standard A/N fittings to generally simulate the geometry of a variable flow rate nozzle considered for use on a high-speed aircraft spray tank. A standard A/N union was welded to the end of the 2-in. supply line. A removable square-edged orifice machined out of an A/N cap formed the minimum area of the nozzle. Six orifices were machined for the test to provide flow rates from 3 to 150 gpm at an injection pressure of 55 psig.

The orifices were used singly but were quickly changeable through a quick-disconnect hatch in the ducting section upstream of the test section.

2.2. INSTALLATION

Propulsion Development Test Cell (J-2)(Ref. 2) is a water-jacketed horizontal test cell, 20 ft in diameter, used for many types of both propulsion system and flow simulation testing at pressure altitudes ranging from sea level to 100,000 ft. The test section was mounted in the test cell as shown in Figs. 9 and 10. A flange from the spray duct section to the 8-ft-diam inlet plenum formed the inlet flow seal. The outlet flow seal was formed by the slip fit of the expansion duct section through a flange attached to the test cell 72-in.-diam exhaust duct. The slip fit was necessary to allow expansion of the assembled test section. This ducting arrangement, by forming a closed flow path from test cell inlet to outlet, allowed testing with the test cell hatch open and thus facilitated access to the holographic equipment.

Airflow to the spray test section was supplied by facility compressors (Ref. 2) through two high-blockage flow-straightening screens located in the 8-ft-diam supply plenum. Airflow rate and flow total and static pressures were controlled by test cell inlet and outlet control valves. Airflow was recompressed and vented to atmosphere by facility exhausters.

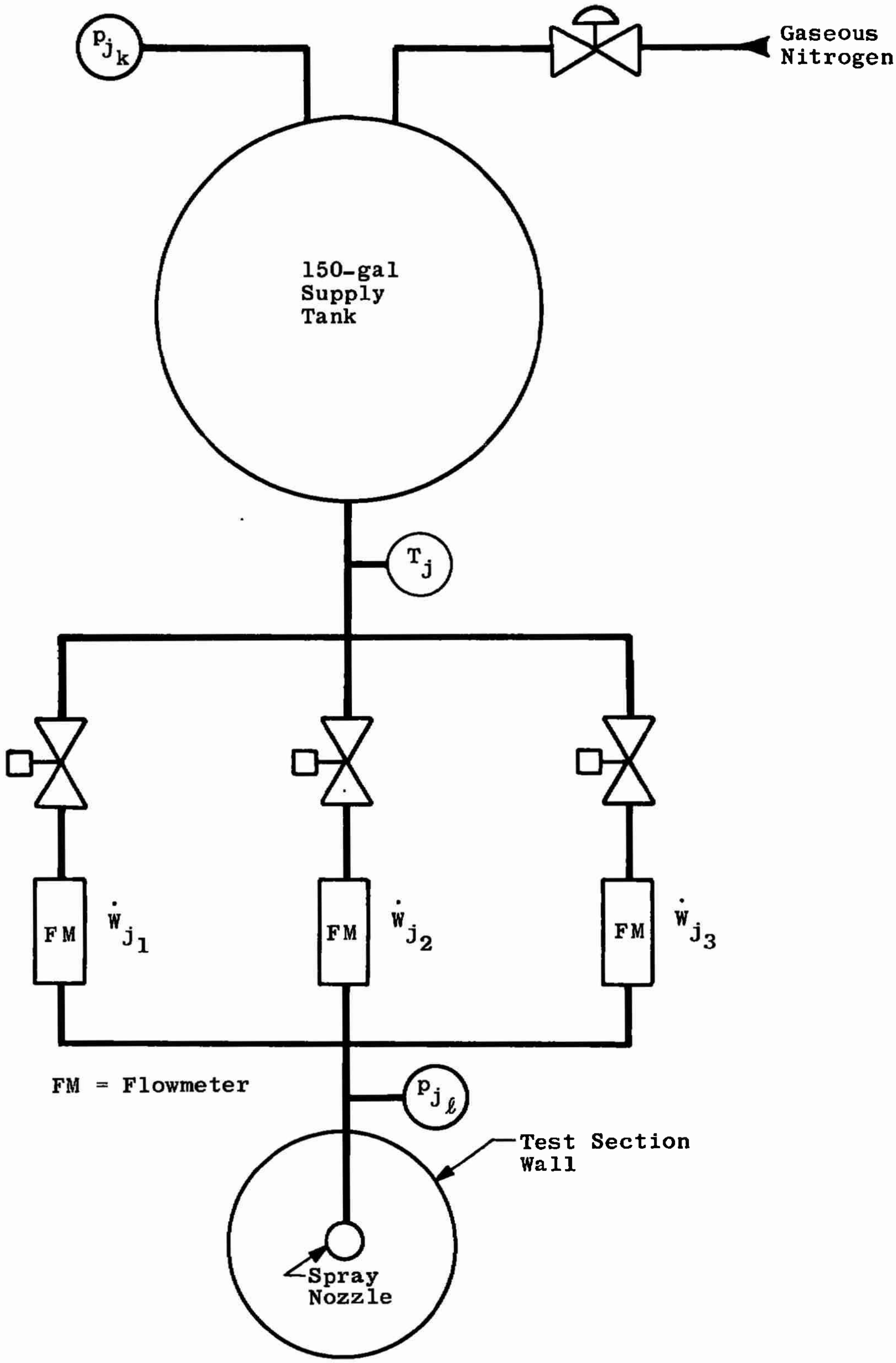


Figure 7. Fluid Supply System

Design Flow Rate, at 55 psig, gpm	Dimension d, in.
3	0.152
10	0.278
17	0.359
25	0.439
75	0.761
150	1.079

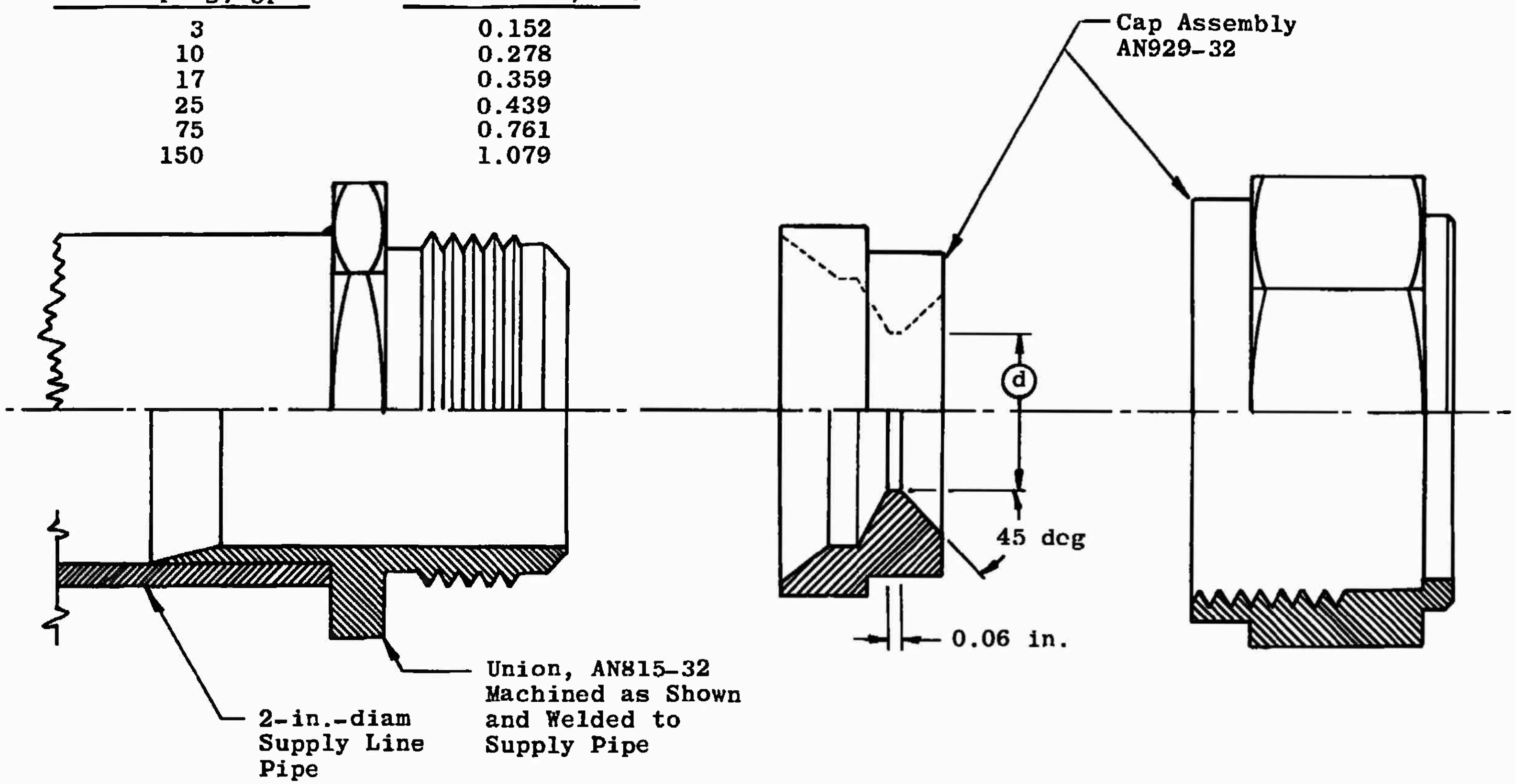


Figure 8. Spray Nozzle

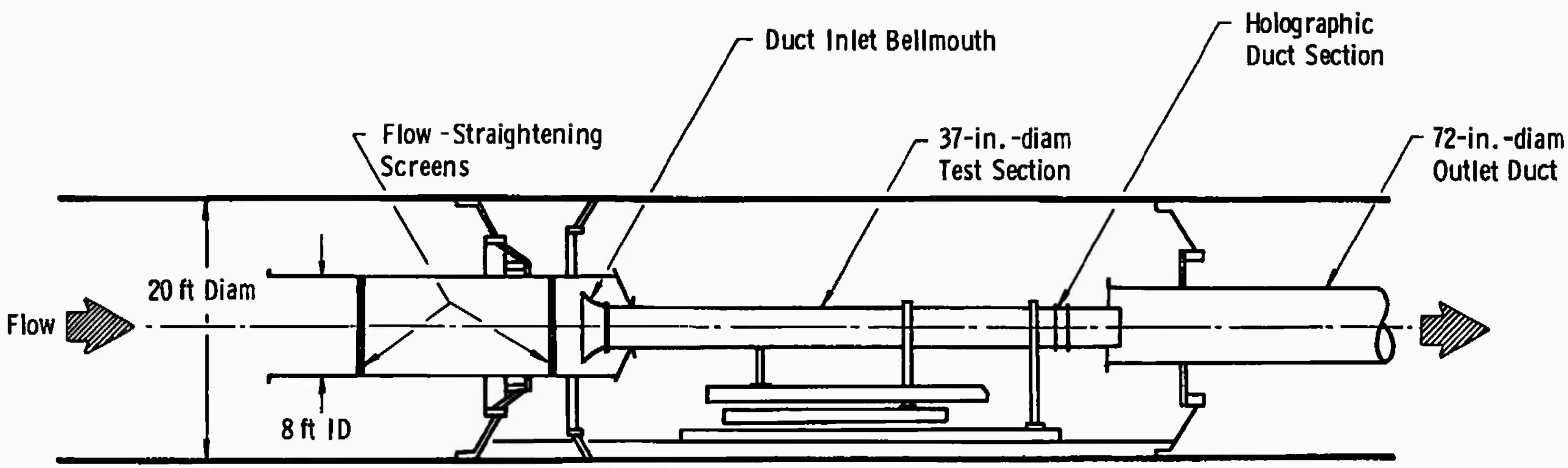


Figure 9. Propulsion Development Test Cell (J-2)

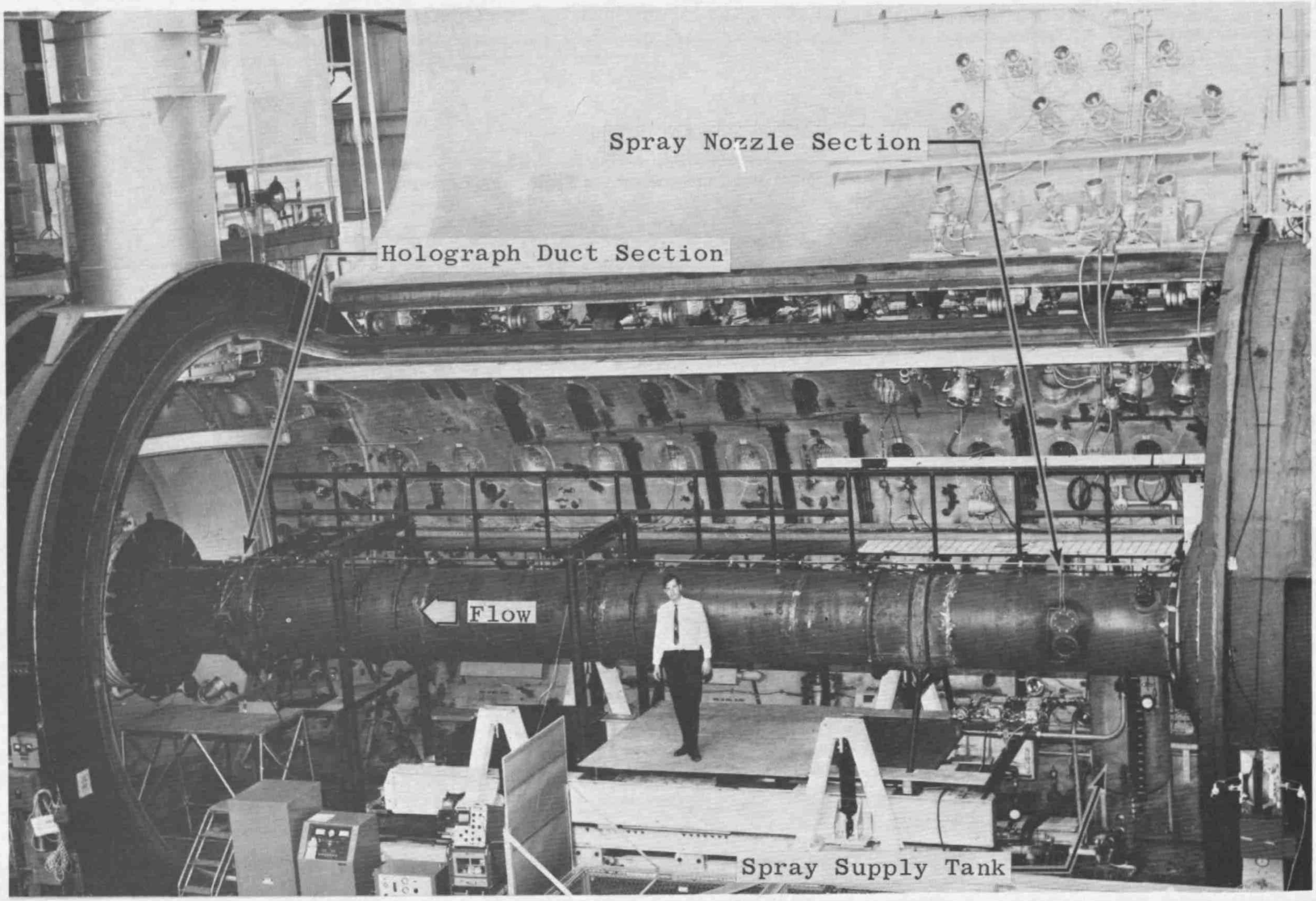


Figure 10. Test Installation

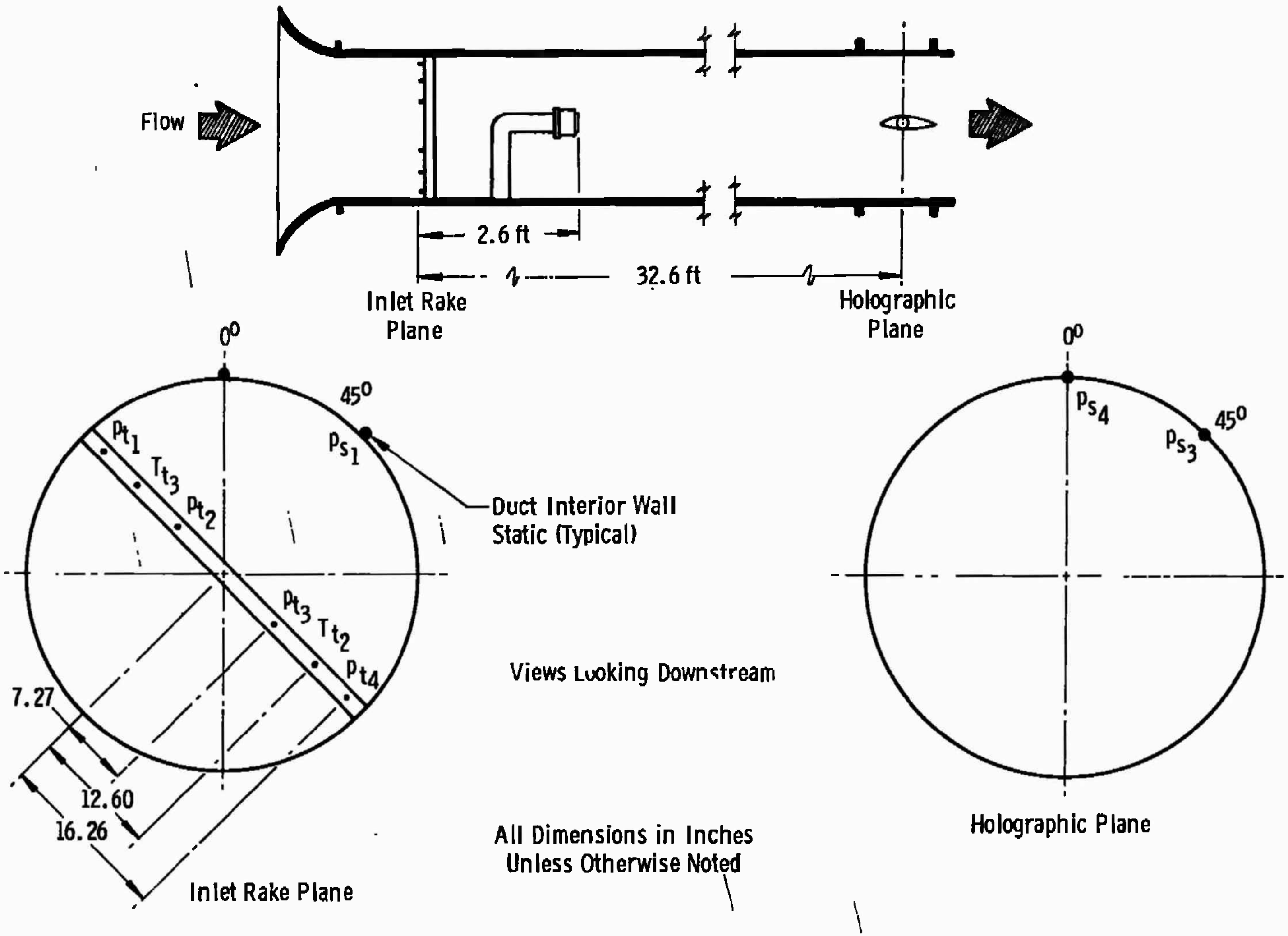


Figure 11. Aerodynamic Instrumentation

2.3 INSTRUMENTATION

Test section total pressure and temperature were measured in the spray duct 2.6 ft upstream of the spray nozzle. Flow static pressures were measured at the spray nozzle and at the holograph airfoil. The locations of the total pressure and temperature rake and static pressure taps are shown in Fig. 11. Spray injection and supply pressures and flow rate and temperature of the simulated defoliant were measured in the fluid supply system (Fig. 7).

2.3.1 Pressures

All aerodynamic pressures were sensed by strain-gage-type transducers with ranges of 0 to 15, 0 to 20, or 0 to 25 psia. These transducers were calibrated in place prior to each test period using an automatic pressure calibration system traceable to the National Bureau of Standards (NBS). Two sigma error of the aerodynamic pressure data is not expected to exceed ±0.5 percent of the reading.

Fluid system pressures were sensed by strain-gage-type transducers with ranges of from 0 to 100 psia. These transducers were laboratory calibrated prior to the test program using standards traceable to the NBS. In-place electrical calibration of the data recording systems for these transducers was accomplished prior to each test period. Two sigma error of the fluid system pressure data is not expected to exceed ±0.8 percent of the reading.

2.3.2 Temperatures

Aerodynamic temperatures were sensed by copper-constantan thermocouples. The spray fluid temperature was sensed by a resistance-type temperature transducer (RTT). The RTT was laboratory calibrated prior to the test program. All temperature data recording systems were electrically calibrated prior to each test period. Two sigma error of all temperature data obtained during the test is not expected to exceed ±3°F.

2.3.3 Flow Rates

Spray fluid flow rate was sensed by one or more impeller-type, reluctance-pickup flowmeters. The flowmeters had ranges of either 2 to 15 gpm or 7 to 75 gpm and were calibrated prior to the test program on a laboratory water flow bench. Two sigma error of the volumetric flow rate data obtained during the test is not expected to exceed ±1.5 percent of the reading.

2.3.4 Data Recording

The sinusoidal frequency outputs of the flowmeters were converted to an analog signal using discriminators. These analog signals, along with the analog signals of all pressure and temperature sensors, were converted to digital signals compatible with the data system digital computer. The digital signals were then recorded on magnetic tape.

SECTION III
PROCEDURE

3.1 PRETEST

Prior to each test period, each test system was checked for functional adequacy. The spray fluid was mixed and pumped into the supply tank. Samples of the fluid were taken for laboratory determination of its viscosity and density. The proper orifice was placed in the spray nozzle. The holograph was aligned and calibrated. Finally, check data points were taken immediately prior to testing to verify proper operation of all data systems.

3.2 TEST

Airflow was initiated, and the desired test conditions were set in the test section. The film pack of the holograph camera was loaded with film, and charging of the laser power supply was initiated. As soon as the charging was complete, flow was started to the spray nozzle. After the spray was fully established, the camera shutter was opened. A limit switch on the shutter actuated the laser which passed a light beam through the spray field. The defracted light beam created a hologram on the film in the camera. Film exposure was controlled by the 10 to 20 nsec duration of the laser pulse. Flow to the spray nozzle was then stopped.

The above procedure was repeated to obtain spray droplet size distribution data at flow rates from 3 to 117 gpm and spray injection pressures from 16 to 64 psig.

3.3 HOLOGRAM RECONSTRUCTION

The holograms obtained during testing were reconstructed on a laboratory optical bench. The coherent, monochromatic, collimated light beam from a 15-milliwatt helium-neon gas cw laser was used to illuminate the holograms. The wave length, 6327 angstroms, of the cw laser used for reconstruction, is near enough to the wavelength, 6943 angstroms, of the pulsed ruby laser used during testing to prevent any significant loss of holographic image resolution.

The holographic image beam was projected onto a vidicon. An optical high pass filter was placed between the hologram and the vidicon to improve the quality of the holographic image. The output of the vidicon was displayed by a standard television monitor. The hologram plate was moved on the optical bench to achieve movement of the reconstructed image plane over the 3.5-in. depth of spray field covered by the hologram.

3.4 DROPLET SIZE DETERMINATION

Polaroid® photographs of the plane holographic image of the droplet field displayed on the monitor screen were taken of each hologram at different depths into the spray field. These photographs were analyzed, and the effective diameter of each in-focus droplet image was measured. The magnification of the droplet images was determined by physical measurement of the image in each hologram of the 150-micron optical port wire (see Section 2.1.2). Diameters of approximately 50 to 400 droplet images were measured from the photographs of each hologram, corrected for holograph magnification, and grouped to obtain histographic distributions of the spray droplet diameters. Care was taken in obtaining, analyzing, and measuring the photographs to ensure that statistically random sampling techniques were not compromised.

3.5 DATA REDUCTION

All pressure, temperature, and flow data recorded on magnetic tape were reduced to engineering units by a digital computer. These engineering unit values were used to calculate test section airstream total and static pressures, together with airstream total temperatures, using the equations below:

$$p_{t_r} = \text{Average of } p_{t_1}, p_{t_2}, p_{t_3}, \text{ and } p_{t_4}$$

$$p_{s_r} = \text{Average of } p_{s_1}, \text{ and } p_{s_2}$$

$$p_{s_i} = \text{Average of } p_{s_3} \text{ and } p_{s_4}$$

$$T_{t_r} = \text{Average of } T_{t_1} \text{ and } T_{t_2}$$

Aerodynamic pressures at locations in the test section other than at the instrumentation rake or at the holograph airfoil were calculated assuming one-dimensional isentropic flow with friction. The wall friction factor of the test section was assumed to be 0.011 for these calculations (Ref. 3).

Airflow velocities in the test section were calculated using the following equation:

$$u = 0.5921\, M \sqrt{\gamma g R T_s}$$

where

$$M = \sqrt{\frac{\left(\frac{p_t}{p_s}\right)^{\frac{\gamma-1}{\gamma}} - 1}{\frac{\gamma-1}{2}}}$$

and

$$T_s = \frac{T_t}{1 + \left(\frac{\gamma-1}{2}\right) M^2}$$

Droplet size distribution parameters were calculated using the equations below:

$$\bar{x} = \frac{\Sigma(x)}{n}$$

$$\bar{x}_m = \sqrt[3]{\frac{\Sigma(x)^3}{n}}$$

$$\psi = \frac{n]_{x_1}^{x_2}}{n_t} \quad \text{where } x_2 - x_1 = 10 \text{ microns}$$

SECTION IV
RESULTS AND DISCUSSION

The objective of the test program was to demonstrate the feasibility of determining the droplet size distribution of a simulated defoliant spray in a high-velocity airstream using in-line holographic photography. Spray flow rate and injection pressure were varied during the test to demonstrate the ability to detect spray parametric relationships.

4.1 TESTING SUMMARY

Five test periods were conducted during the test program (Table III). However, the first three periods were used either to check out test equipment or to verify the adequacy of equipment modifications necessary to eliminate malfunctions that occurred during prior checkouts (see Section 4.5). During the last two test periods, 27 holograms were taken of the simulated defoliant spray field in the high-velocity test section airstream. Holographic droplet size data were obtained at spray nozzle flow rates, areas, and injection pressures from 3 to 117 gpm, from 0.15 to 1.08 in^2., and from 16 to 64 psig, respectively (Table IV).

4.2 TEST CONDITIONS

Aerodynamic conditions in the test section were essentially the same for all 27 holograms. Velocity and static pressure at the spray nozzle were approximately 370 knots and 14 psia, respectively (Fig. 12). However, duct wall friction losses accelerated the test section airstream so that velocity and static pressure just upstream of the holograph airfoil were approximately 430 knots and 12 psia, respectively. As a result, average airstream velocity in the nozzle spray field was approximately 400 knots. Airstream total temperature was constant at approximately 50°F throughout the test section.

Spray fluid control valves were opened 3 to 4 sec prior to actuation of the laser so that all 27 holograms were taken under steady spray flow conditions (Fig. 13). Spray flow rates and injection pressures were selected as shown in Table IV by proper choices of nozzle orifice areas and spray supply tank pressures.

TABLE III. TESTING SUMMARY

Test	Date	No. of Flow Holograms Taken	No. of Valid Flow Holograms	Remarks
CK-01	January 27, 1970	0	0	Holograph damaged by ducting vibration
CK-02	February 4, 1970	6[a]	0	Optical ports coated by spray fluid
AA-01	February 5, 1970	19	0	Optical ports coated by spray fluid
CK-03	February 11, 1970	10[b]	9[b]	
AA-02	February 12, 1970	18	18	

[a] Water was used as the spray fluid for this checkout test to conserve simulated defoliant.

[b] This does not include 1 valid and 5 invalid holograms taken using water as spray fluid to verify operation of the holograph.

TABLE IV. LISTING OF VALID HOLOGRAMS

Test	Hologram	Spray Nozzle Orifice Diameter, in.	Spray Flow Rate, gpm	Spray Injection Pressure, psig
CK-03	11-8	0.152	3	61
	11-9		3	62
	11-10		3	63
	11-11		3	64
	11-12		3	64
	11-14	0.278	10	55
	11-15		10	55
	11-16		10	55
	11-17		10	56
AA-02	12-3	0.359	21	58
	12-4		18	56
	12-5		15	38
	12-6		15	39
	12-7	0.439	22	40
	12-8		22	38
	12-9		26	56
	12-10		26	56
	12-11		26	58
	12-12	0.761	64	36
	12-13		63	36
	12-14		54	25
	12-15		54	26
	12-16		45	17
	12-17		45	17
	12-18	1.079	117	27
	12-19		115	27
	12-20		116	27

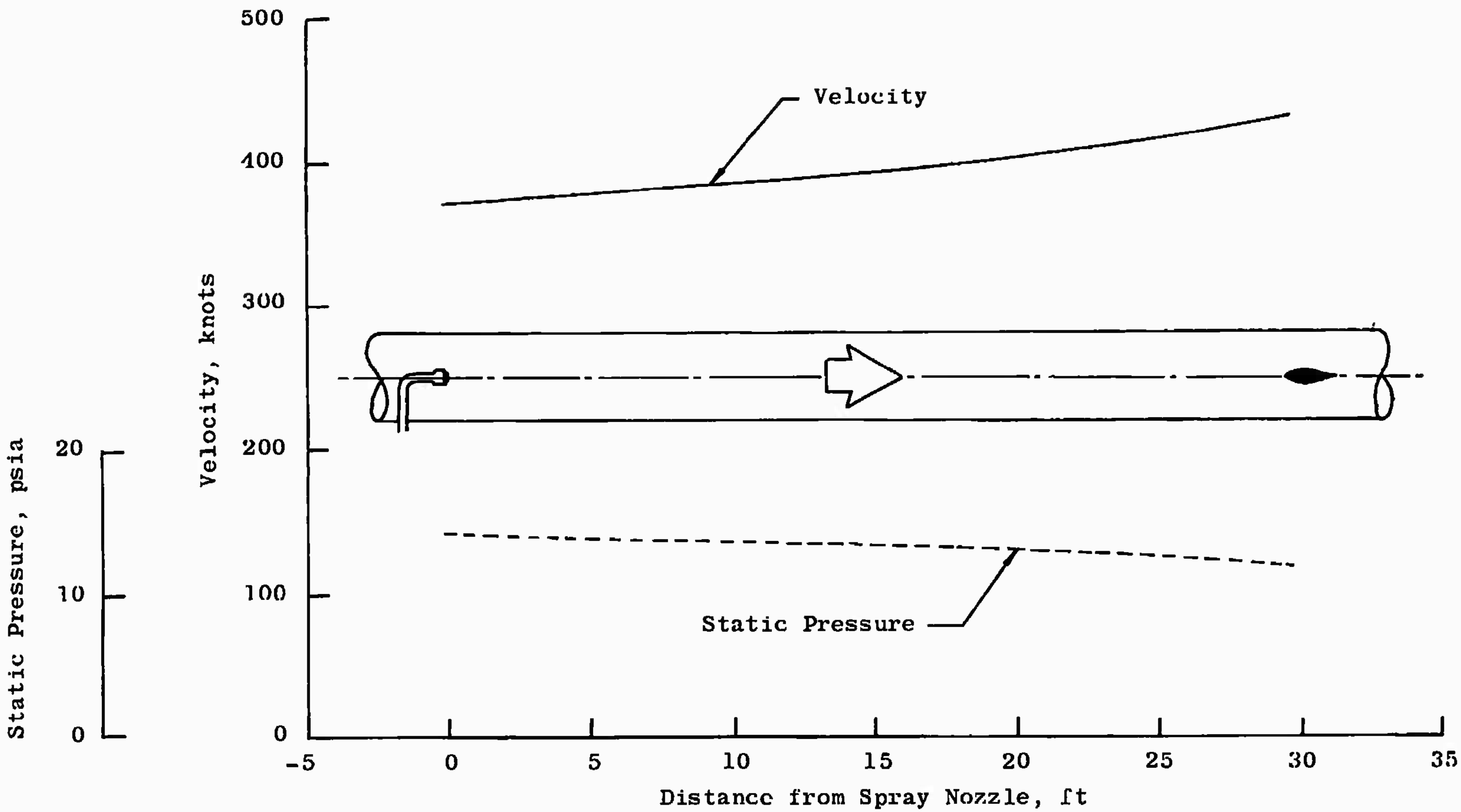


Figure 12. Test Section Velocity and Static Pressure

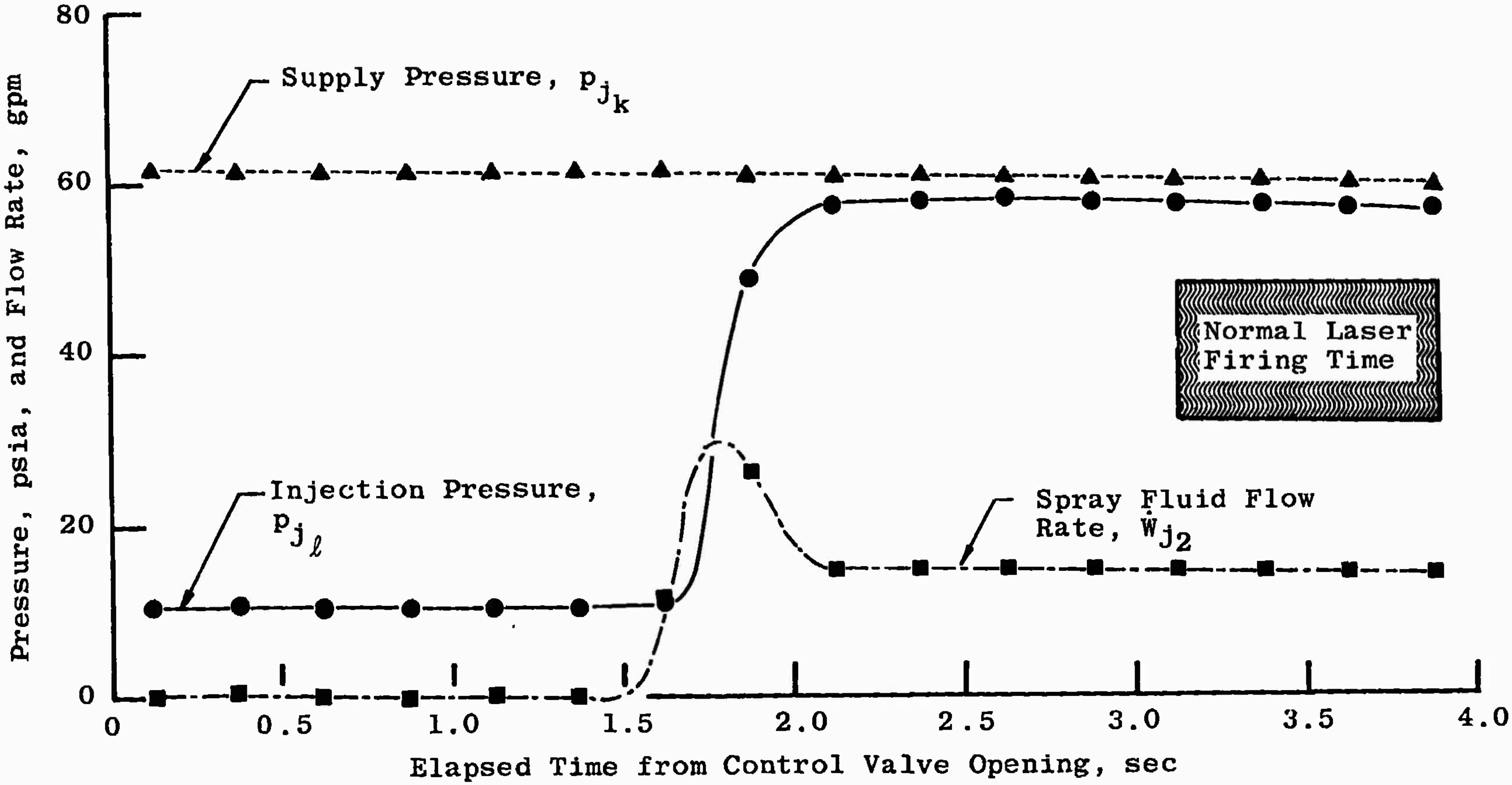


Figure 13. Typical Spray Flow Sequence

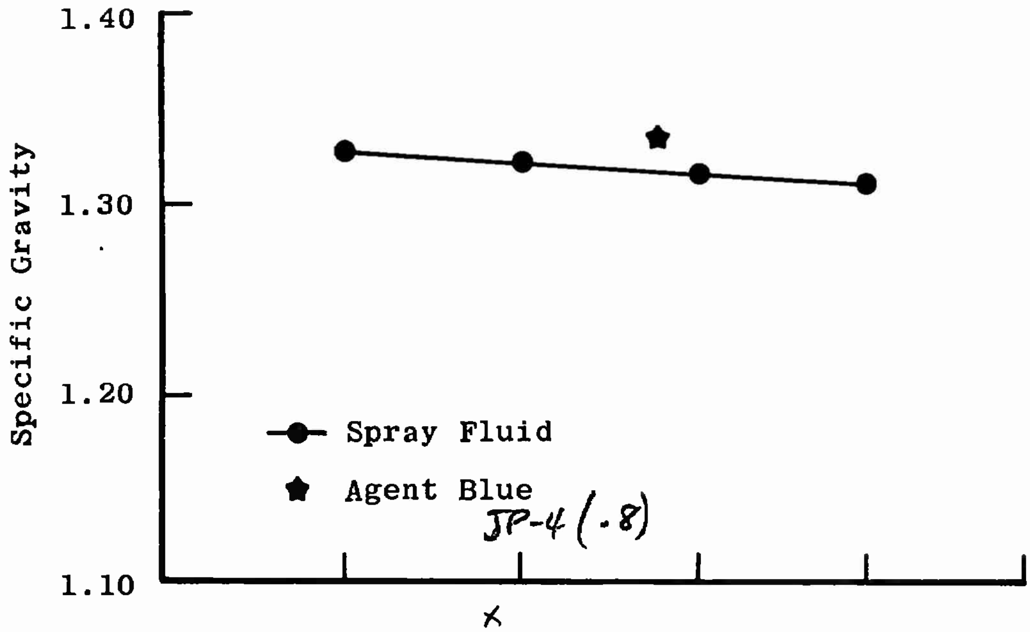
Laboratory analysis of the spray fluid used during testing indicated that its viscosity and specific gravity (Fig. 14) were quite close to those of the defoliant Agent Blue being simulated. No measurements of spray fluid surface tension were made. However, similar mixtures have been used before, and their surface tensions were determined then to be sufficiently close to that of Agent Blue.

4.3 SPRAY DROPLET SIZE DATA

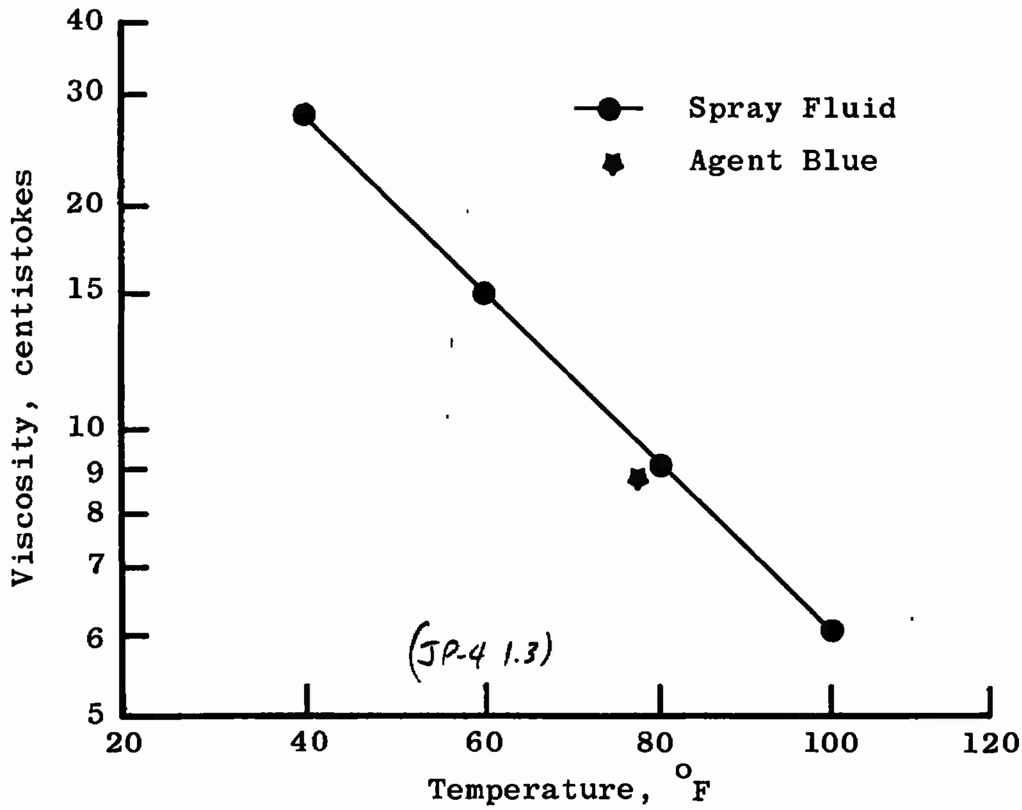
Six of the 27 valid holograms obtained during testing were chosen to be representative of all test conditions and were analyzed (Fig. 15 and Table V) to obtain the droplet size distribution of the simulated defoliant spray. A total of 1026 droplets was measured. Histograms (Fig. 16) of the droplet size data from each of the six holograms and a histogram (Fig. 17) of the diameters of all 1026 droplets measured indicated that spray nozzle flow rate, injection pressure, and area do not appreciably affect the droplet size distribution. Average droplet diameter of data from the six holograms varied from 17 to 23 microns. Average diameter ($\overline{x}$) of the 1026 droplets was 21 microns. Average mass-weighted diameter ($\overline{x}_m$) of the droplets was 24 microns. No droplet was found that exceeded 50 microns in diameter.

4.4 HOLOGRAPHIC RESOLUTION LIMITS

Theoretical diametric resolution limit of the holograph used during testing is approximately three microns. Pretest holograms taken without either airflow or spray flow of a wire grid in the middle of the holographic test volume resolved a 6-micron-diam wire distinctly. However, resolution of the holograph is also a function of the spray field density (Ref. 4), and therefore, a resolution limit of 10 microns was semi-arbitrarily chosen for analysis of the holographic data. Images having diameters less than 10 microns can be seen on the data photographs (Fig. 15), but it cannot be determined with certainty that these images are actually droplets.



a. Specific Gravity



b. Viscosity

Figure 14. Physical Properties of Spray Fluid

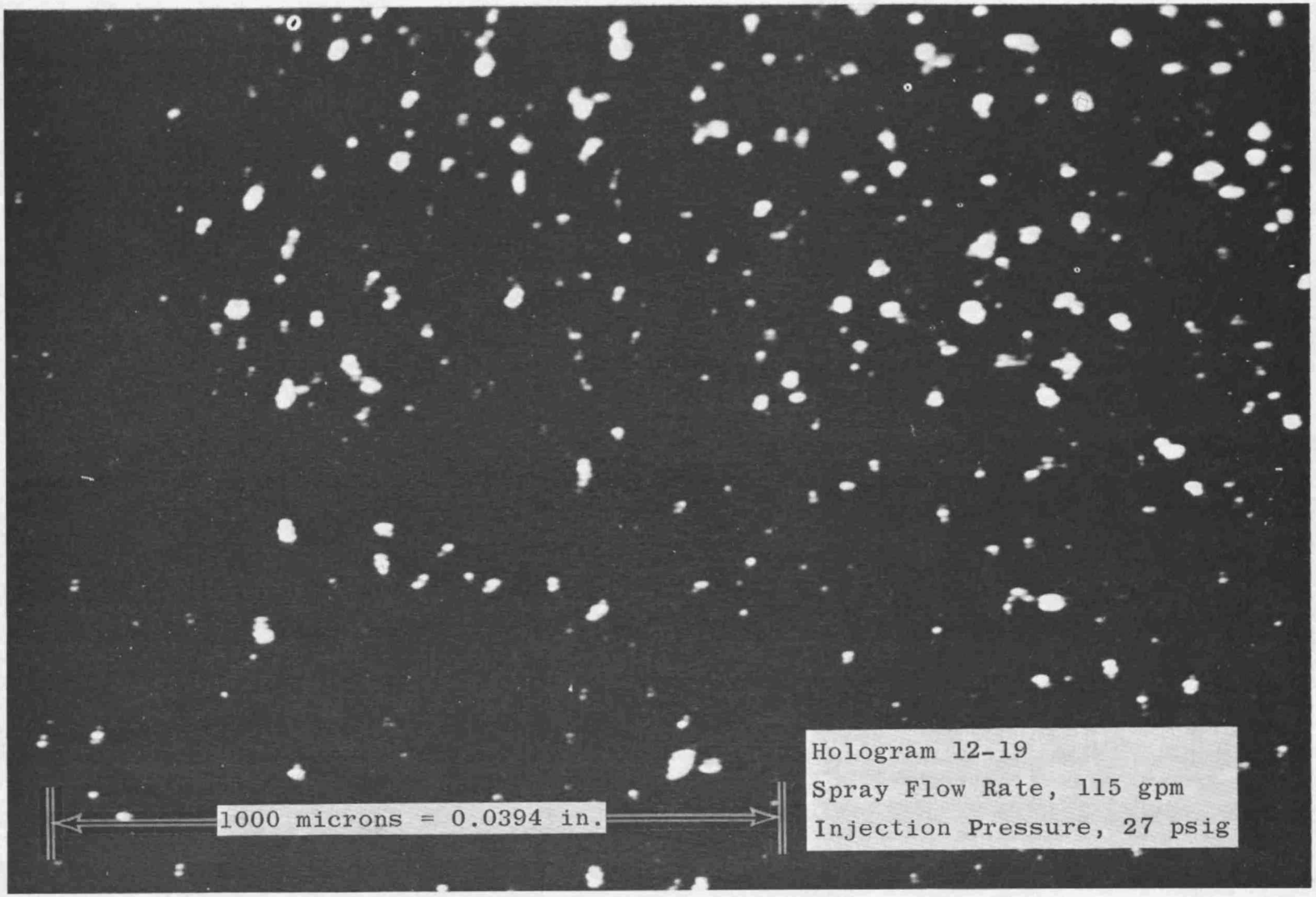


Figure 15. Typical Spray Droplet Field Photograph

TABLE V. HOLOGRAPHIC DROPLET SIZE DATA

Hologram	Spray Flow Rate, gpm	Spray Injection Pressure, psig	Distance from Camera-Side Airfoil, in.	Size Distribution, microns 10-20	20-30	30-40	40-50	n	$\bar{x}$, microns
11-12	3	64	0.81	7	29	6	2		
			1.01	5	29	4	2		
			Total:	12	58	10	4	84	23
11-15	10	55	0.38	40	2	1	0		
			0.71	25	6	2	0		
			1.05	58	16	0	0		
			Total:	123	24	3	0	150	17
12.3	21	58	1.76	10	9	4	0		
			1.92	5	7	4	1		
			2.23	10	15	8	1		
			2.62	12	17	3	0		
			Total:	37	48	19	2	106	24
12-7	22	40	1.52	7	32	3	1		
			1.64	10	15	2	2		
			1.72	7	19	4	1		
			1.84	11	23	1	0		
			1.92	8	8	0	0		
			2.31	6	9	0	0		
			2.70	15	7	1	1		
			Total:	64	113	11	5	193	23
12-16	45	17	1.56	16	27	20	1		
			1.68	14	15	3	1		
			1.76	20	15	3	1		
			1.84	35	12	2	0		
			1.94	36	15	6	1		
			2.03	35	10	6	0		
			2.23	33	12	5	0		
			2.70	22	3	3	0		
			Total:	211	109	48	4	372	21
12-19	115	27	1.52	44	22	5	2		
			1.76	29	11	6	2		
			Total:	73	33	11	4	121	21

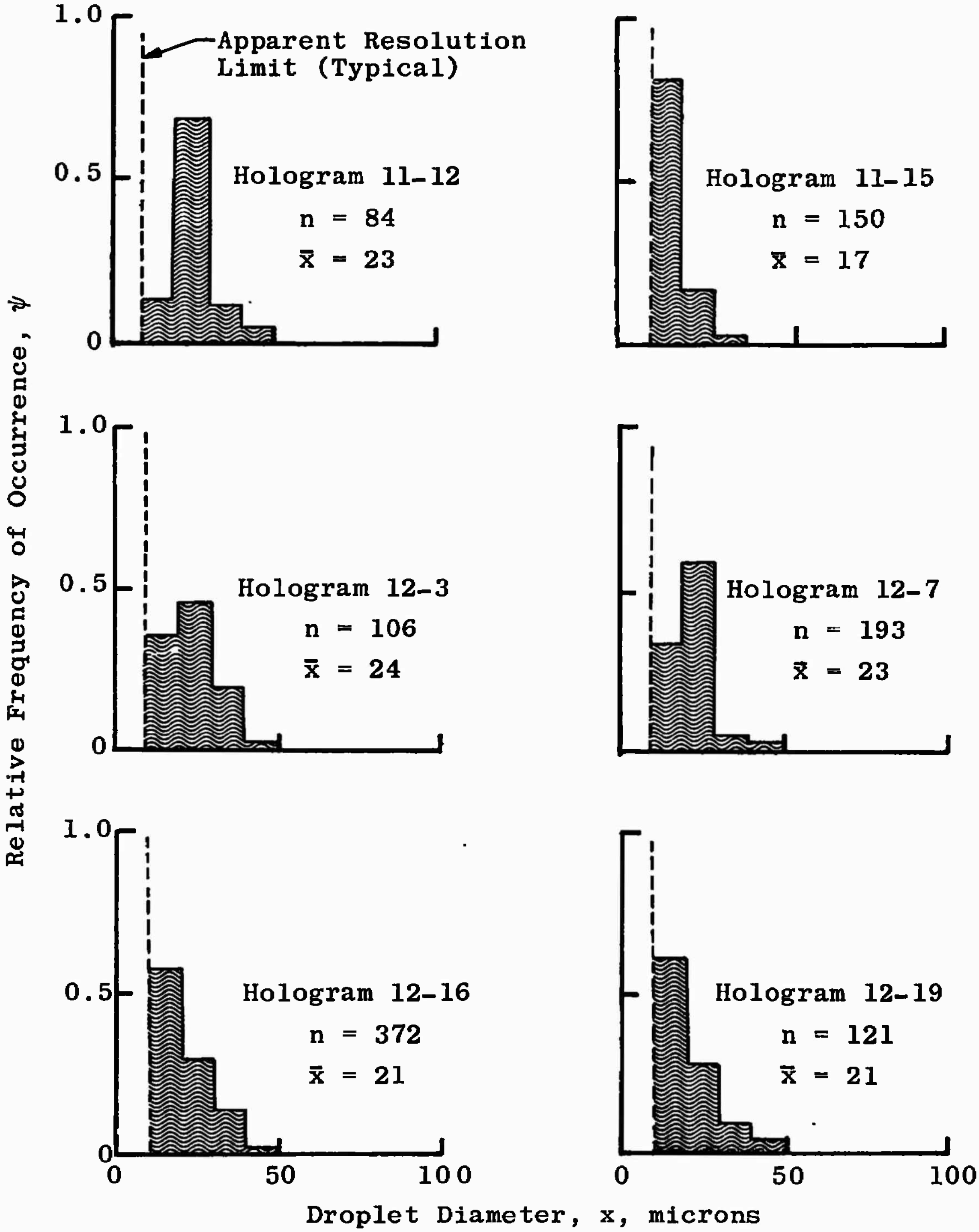
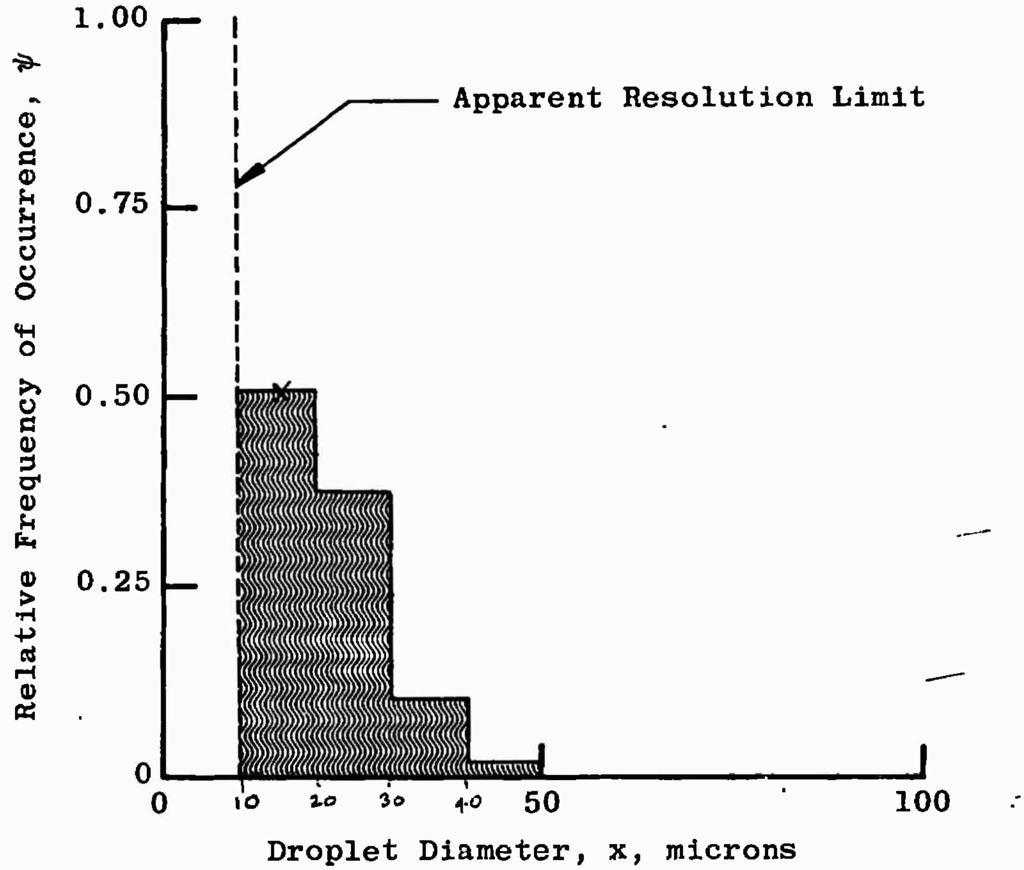


Figure 16. Spray Droplet Size Histograms



DROPLET SIZE DATA SUMMARY

Droplet Diameter, x	10-20	20-30	30-40	40-50	>50
Number of Droplets, n	520	385	102	19	0
Average Droplet Diameter, $\bar{x}$	21.3 microns				
Average Mass-Weighted Droplet Diameter, $\bar{x}_m$	23.8 microns				

Figure 17. Overall Spray Droplet Size Distribution

4.5 HOLOGRAPH RELIABILITY

The holograph was initially attached to the test section ducting. During the first checkout test, vibration of the ducting caused the dye-cell of the laser Q-switch to fracture. Also, several optical components were either loosened or misaligned by the vibration. Vibrational displacement of the ducting was later determined to vary between 0.010 and 0.020 in. rms. The holograph laser was detached from the ducting and shock-mounted to the test cell floor for the second checkout test. This modification reduced the vibrational displacement of the holograph to less than 0.0003 in. rms. No further malfunction of the laser was encountered, although vibration of the camera shutter and its laser-actuation limit switch, which remained attached to the ducting, was a continual minor problem during the remainder of testing.

Analysis of attempts to obtain holographic data during the second and third test periods indicated that the spray nozzle effluent was coating the optical ports at the end of the airfoils. This coating caused sufficient scattering of the laser light pulses to invalidate the holograms. The purge system on the optical ports was modified to provide both increased purge flow rate and pressure. This modification was adequate, although occasional cleaning of the optical ports was necessary to obtain the 27 holograms from the two final tests of the program.

Another problem encountered was the vibrational loosening of black paint that was used to prevent reflection of the laser beam within the airfoils. Particles of the paint coated both the optical ports and the optics inside the camera side airfoil sufficiently on occasions to significantly reduce the image quality of the holograms.

No other holographic system difficulties were encountered; however, care had to be taken in adjusting the laser power supply to avoid multiple pulsing of the laser.

SECTION V
SUMMARY OF RESULTS

The results of a test program to demonstrate the feasibility of determining the droplet size distribution of a simulated defoliant spray in a near-sonic airstream using in-line holographic photography may be summarized as follows:

1. Holographic droplet size data were obtained in a 400-knot airstream at spray flow rates from 3 to 117 gpm and spray injection pressures from 16 to 64 psig.
2. Average diameter of the spray droplets was approximately 21 microns and did not vary significantly with either spray flow rate or injection pressure.
3. The droplet-size-measurement hologram exhibited an apparent diametric resolution limit of 10 microns.
4. Operational reliability of the holograph was satisfactory.

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13. ABSTRACT

The feasibility of determining the droplet size distribution of a simulated defoliant spray in a high-velocity airstream using in-line holographic photography was successfully demonstrated. Holographic droplet size data were obtained in the 400-knot airstream contained within a 37-inch-diameter duct at spray flow rates from 3 to 117 gpm and spray injection pressures from 16 to 64 psig. Average diameter of the spray droplets was approximately 21 microns. Droplet size distribution did not vary signficantly with either spray flow rate or injection pressure. The holographic measurement system exhibited an apparent diametric resolution limit of approximately 10 microns. Operational reliability of the holograph was satisfactory.

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Droplets						
Defoliation						
Spray dispersion						
Spray nozzles						
Aerial delivery						
Droplet size distribution						
Spray flow rate						
Spray injection pressures						